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LITERARY.
SURGEON GENERAL'S OFFICE

JUL 20 1909

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STANDARDS OF FORM AND COLOR-VISION REQUIRED IN RAILWAY SERVICE.¹

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IF we consider the present condition of railway service in this country we find that express passenger trains often reach a speed of sixty miles an hour during some portions of their runs. With a train of four or five Pullmans and a baggage car, running at this speed, a distance of about 1,500 feet is needed, on level track, in which to recognize the signal, apply the brakes and bring the train to a stop, if necessary. Important points are guarded by Semaphore signals, which have a movable arm about $4\frac{1}{2}$ feet in length, and from 7 to 10 inches wide. When seen at a distance of 2,500 feet, such a signal will subtend with its average width the same visual angle as the width of Snellens xx foot test letters at 20 feet, that is, one minute; but as the length of the signal is more than five times its width, the length will subtend a little more than the standard angle of five minutes, which corresponds to the height of Snellen's test letters and is the visual angle under which they should be read by a normal eye. A Semaphore signal of this shape has been found the best for conditions of service, and if it is seen against the clear background of the sky, its position, horizontal for danger, or at an angle with the horizon for

¹ Read at the meeting of the American Ophthalmological Society, in Washington, D. C., May 6th, 1897.

safety, can be easily seen under favorable conditions of atmosphere and background at a distance of over a mile. Such conditions are not always found; the air may be hazy or smoky, or the background may be a building, a bridge, a green or brown hillside, etc., which will seriously interfere with the visibility of the signal. Again, in rain, snow, or fog, such a signal cannot be seen until the train is very near to it, so in addition to the red home signal near the point to be protected, another green or distant signal is placed at about 1,500 feet¹ from the first, and is operated to correspond with it. In bad weather, the position by day, or the color by night, must be seen by the engineer as he passes this distant signal, and there is no time for hesitation in recognizing it, if danger is shown, for, if the train be moving at the rate of sixty miles an hour he will need the whole distance between the distant and home signal in which to stop his train, and there will be only fifteen seconds before the train, if unchecked, will have reached the danger point, or if the speed be thirty miles an hour, the time will only be extended to thirty seconds. It is, therefore, essential not only that our railroads should be equipped with the best of signals and safety appliances, but also that those employed in the operation of railway trains should have such acuteness of vision and color-perception that they can recognize these signals quickly and accurately, even under unfavorable conditions, and in this paper your attention is called to the methods of examination and the standards which should be employed to make sure that railway employes have a safe amount of form and color-sense.

Defects in acuteness of sight are much more common than those of color-perception. On the Burlington system in six

¹ On many roads the distant signal is placed at from 1,000 to 2,000 feet from the home signal, on a rising grade, and 2,000 to 3,000 feet on a falling grade.

years 344 men were rejected for defects of sight and 176 for color, and a careful examination will show not only that defects of sight greatly outnumber those of color, but also that many cases of poor vision are acquired after entering the service, thus making it necessary to have periodical re-examinations of form-vision, whereas, if the original tests of color-sense have been carefully made it will be found that very few cases of poor color-perception are afterward developed, unless there is an accompanying failure of form-vision, which will be discovered by a periodical re-examination of the sight.

Two standards should be required for entrance to the service, a higher for those whose work will be on the head end of a train and in other important positions, and a lower for other operating men. Again, a higher standard should be required in each of those classes for entrance to this service than will suffice for a continuance of duty after years of service. There is no injustice in requiring a high physical standard of men seeking certain kinds of work, and there is no difficulty in obtaining such men; the trouble comes when men are discharged, after years of faithful work, for defects which could have been discovered at the start, if a careful examination had been made at that time.

There is a great variation in the standards of vision required on various roads and in various countries. In Holland, where oculists of the highest standing, have had charge of this matter, the rules require for Class A (engineers and firemen), with both eyes open, normal vision; with each eye separately, the other being covered, normal vision in one eye, and not less than one-half in the other, without glasses; also normal refraction. For Class B (station masters, conductors, brakemen, switchmen, etc.), with both eyes open, normal vision, without glasses, free

from hypermetropia of more than one diopter; with each eye separately, in one eye normal vision, in the other not less than one-quarter, without glasses. The vision is measured by Snellen's test types. In England a committee of the British Medical Association, after a careful investigation, recommended in their report in 1892, for Class A (engine drivers, cleaners, firemen, signalmen and points-men), in one eye normal vision and refraction, in the other eye not less than one-half of normal vision, without glasses. For Class B (all other situations in the executive service concerned with the moving and signalling of trains), with both eyes open, visual acuteness of not less than two-thirds of normal without glasses, provided that neither eye has less than one-third of normal vision without glasses, using Snellen's test types. In Belgium, for Class A, in one eye 20-20, in the other not less than 20-30; for Class B, in one eye 20-20, in the other not less than 20-40. In Bavaria, for Class A, 20-40 without glasses is allowed (this class here includes all out-door employes), and for re-examination not less than 20-40 with glasses.

On the N. Y. C. & H. R. R. R. for a first-class certificate, vision of at least 20-30 is required, but if one eye has 20-20 and the other 20-40, it will answer. For a second class certificate, for yard service only, not less than 20-40 is required, but if one eye has 20-20 and the other 20-200, it is accepted for a second-class certificate. On the Pennsylvania System 20-20 in one eye and not less than 20-50 in the other is considered satisfactory, with or without glasses. On the Burlington System, for entrance to the engine service, 20-20 in each eye is required, and for the train and yard service, 20-20 in one eye and not less than 20-40 in the other, without glasses in all cases, each eye being tested separately.

It will be seen from the above that the standards of required vision for the first class vary in different places from 20-20, or normal vision in each eye, down to 20-40 in each eye. In some cases provision is made for re-examination, but in many places no separate standard is required for this. The test in general use is Snellen's test letters, although in England some roads use the army test cards, with dots instead of letters. The principal objection I have found to the ordinary Snellen's letters for this work is that they are all printed on one card, and it is not difficult for men who are to be tested to provide themselves with copies of the card in order to memorize the letters. In one case a man read easily the xx line at 20 feet, who was found to have less than 20-40 vision, as he could not read either the xxx or the xl lines at 20 feet when called on to do so unexpectedly by the examiner.

In order to overcome this difficulty, and also to provide a more convenient form of test card, I had letters of Snellen's standard sizes printed on a series of separate cards, one line on each card, and for each distance had three cards with a different arrangement of letters on each. In testing a person, one of the xx foot cards is placed in a good light, twenty feet from him, and he is asked to read it, one eye being covered. If he does so correctly another of the xx foot cards is shown for a second trial, the other eye being covered. He cannot tell which of the cards he will be asked to read, so that even if he had memorized them all he would have to see the letters in order to read the cards correctly, and as there are no letters of a larger size on the same card he could not recite from memory the smaller letters by means of the larger ones that he could see. If he cannot read the xx foot line at 20 feet, then the xxx, xl, l, or the lxx foot letters are shown in succession, until letters are

found that he can read, or if he cannot read the lxx line at 20 feet he is brought nearer until a point is found where it can be read, or if he cannot see it at any distance the fact is so noted. This test has been in use on the Burlington System since 1893, and has given good satisfaction. I have recently been experimenting with another test card, with figures made to represent a line of semaphore signals, such as are often placed on a bridge crossing the tracks, or at the entrance to a union station. On this card the length and breadth of the arms correspond to the height and breadth of the Snellen's letters for xx feet, and also nearly correspond, when looked at from a distance of 20 feet, to the size of a standard semaphore arm when seen at a distance of a half a mile. I find, when the relative visibility of this signal card is compared with the corresponding Snellen's letters, that the card of signals of the same size as the xx foot letters can be clearly seen nearly as far as the xxx foot letters, for with the signals the only point is to recognize quickly and accurately the position of the semaphore arm, as to whether it stands horizontally at danger, or at an angle with the horizon at safety; but with the letters small differences of shape must be recognized; it is very easy to confound the C. G. D. O. and some others, and such mistakes should not be rejected.

A railroad company should require 20-20, or normal vision in each eye without glasses, and less than two diopters of hypermetropia of all persons seeking employment in its engine service, who will be required at any time to act as engineman or fireman. After years of service the requirements may be reduced for Class A to not less than 20-30 of normal vision in one eye and 20-40 in the other with the test letters, each eye being tested separately without glasses, but less than this should not be allowed on

the head end of a train. The same standard should be required for men in signal towers, in charge of interlocking signals and switches, and draw bridges. For the general train and yard service, Class B, lower standards may be allowed. For entrance to this class, 20-20, or normal vision in one eye, and not less than 20-40 in the other, without glasses, should be required. After years of service, on re-examination, this might be reduced to not less than 20-30 in one eye and 20-70 in the other, without glasses. In addition to reading the test letters by candidates for employment, a simple test for refraction, which can be made by any medical examiner, should also be used in all cases. We may leave out of the question the conditions of myopia and astigmatism, for, if present in any amount, they would cause enough defect in sight to bring the vision below the required standard, but a young man of twenty-one years of age or thereabouts, may be able to read easily the xx line at 20 feet with each eye, and yet have a hypermetropia of two diopters, or more, which by the time he is forty-five years old, or sooner, will reduce his visual acuteness for distant objects below the standard required, and it is not just to such a man to accept him for the service, and then retire him when he is too old to learn another business, because he does not then come up to the visual standard required, without glasses, although he may have had normal vision in each eye when he first applied for work. Such hypermetropia can be easily detected by asking the applicant to read the xx line of test letters on another card at 20 feet while looking through a convex lens of two diopters; if with each eye he can read the letters correctly through this glass he should be rejected, for it shows he has a hypermetropia of two diopters or more. A test for refraction

with the ophthalmoscope would be better than the above, but we must bear in mind that these tests must often be applied by medical men who have had no special training in ophthalmology, and with a large system of railroads like the Burlington, having more than 7,000 miles of track, it is impossible to have men brought in to central points over great distances for examination when they apply for work.

I recently had a case to examine where the vision of an engineer had been reduced to 3-10 of normal in each eye. There was no other trouble except a hypermetropia of three diopters, and with proper glasses the vision was brought up to normal in one eye and 9-10 in the other. He was transferred to other work in which he could use his glasses, but in this case the simple test with a convex glass would probably have shown the trouble at the first examination for entrance to the service.

A periodical re-examination of the form-vision should be required of all men employed in the operation of trains or signals every three years, for the sight is often impaired by disease that may show no outward change, and such re-examination should also be made before promotion, after serious illness or injury, after accidents which might have been due to defective sight, or when from excessive use of tobacco or other cause it is deemed necessary.

The certificate of examination given to the man should state the date of examination, the occupation which the certificate covers, and whether or not any defect is found in the acuteness of vision, color-perception or hearing, and the certificate should be signed both by the examiner and the person examined.

In all examinations of sight, care should be taken to see that uniform and accurate test letters are used. Within a

month my attention has been called to sets of test letters, recently published, in which there was a considerable variation in the size of the letters to be read, at 20 feet, on different cards published by the same firm. The illumination of the letters should also be clear and as constant as possible, the card being hung where it gets the daylight full upon it, but not in the sunshine or where the person reading it will have to look directly toward a strong light.

The examination blank used on the N. Y. C. & H. R. R.R. does not provide for any test for the range or field of vision, and in my experience I have never known a person to be rejected for a defect in either of these things when the acuteness of vision came up to the required standard. It is, however, well to have a reading test in order to make sure that the person examined can read both print and written train orders at the ordinary distance, and I have known an engineer who was found by this test to be unable to read, although he had normal vision, knew his letters and could sign his name; he was in the habit of getting his fireman to read all train orders to him, but when this condition was discovered he was laid off until he could learn to read, and write more than his signature.

In regard to the use of glasses, the instructions of the Pennsylvania Railroad say: "If one eye has 20-20 and the other eye not less than 20-50, with or without glasses, the sight may be considered satisfactory," but no statement is made as to whether this will be satisfactory for an examination for entrance to the service, or only for re-examination, or whether glasses will be allowed on duty. It will be found in practice that glasses for distant vision cannot be worn on duty by enginemen and others whose work requires them to be out of doors in all kinds of weather, for steam, rain, smoke and

snow interfere seriously with their use. For this reason the acuteness of distant vision for these men should always be tested without glasses. With cases of simple presbyopia it is different. Here the distant vision remains unimpaired, and when glasses are needed for occasional use, as in reading train orders, they are not incompatible with good service; the presbyopia will have to be considerable before it will interfere with the telling of time by a watch or the reading of steam or water gauges without glasses.

The standard examination for color vision should include three things: 1, a test with colored signal-flags; 2, a test by comparison of colors by the Holmgren worsteds; 3, a test with colored lights seen through openings of regulated size, which will form small images on the central part of the retina. The acuteness of color-vision varies considerably from the normal standard, as does form-vision. We may have a feeble color-perception, an incomplete loss of color-sense, generally for red and green, or a complete loss of perception for one or both these colors, and in rare cases a complete loss of all color-perception, in which the solar spectrum looks like a gray smear of varying shade but no color.

The object of our tests is to discover the extent and character of the defects, and whether they are sufficient in amount to disqualify according to the standards adopted. The test with flags shows whether the man can give correct names to the flags, and can tell their use and meaning. It is also desirable to use one of the flags at a time as a test object, and get the applicant to pick out from the heap of Holmgren's worsteds all the colors that look like the flag. It will often be found that correct names can be given to the different flags even when the tests by

worsted and colored lights show a considerable defect of color sense, but when used as a comparison test a green may be selected among other colors as looking like a red flag, or *vice versa*. The second test, by comparison of colors without naming them, selecting from a large number those which appear to the applicant like certain test-skeins, light green or pink, according to the method proposed by Professor Holmgren, is the most satisfactory and easily applied of all the good qualitative tests, but it does not give a sufficient test for small central scotomata.

I have recently had a conductor, who passed both the Holmgren and the Thomson tests without making a single mistake, and who selected his colors without hesitation, but when examined by colored lights transmitted through small openings, or even with switch-light lenses, before a lamp at 20 feet distance, he called a red light "white" in four different cases; he had a central defect in the retina, probably caused by the use of tobacco in excess, yet the area affected was so small that the retinal image of the flag or the skein of worsted was formed partly on the diseased retina and partly on the healthy portion outside the scotoma, where the color could be easily recognized, but when the retinal image was reduced in size, as with the lights, it was formed entirely within the borders of the scotoma, and red lights were called white or sometimes green. It will not do, however, to substitute the tests with such lights for the Holmgren test, as the lights give little chance for comparison or for the selection of confusion colors, and for ordinary cases of congenital color defect it would take a long and tedious examination to reach the same result that could be arrived at more quickly by the worsted test. On the other hand the test with lights, with regulated openings, should be used in addition to the worsted test, as was first proposed in

Holland. The regulations of the Dutch railways specify that a quantitative test for color-sense be made in every case by Donders' method. In his instrument the light from a standard candle is allowed to fall on a disc carrying red, green, blue and ground glasses, and in front of this disc is a diaphragm with openings of 1, 2, 5, 10 and 20 m.m. diameter. The color can be changed by rotating the disc, and the man is requested to name the color as seen through the smallest opening when placed five meters from him; if he cannot do this he approaches the instrument until the colors can be recognized or a larger opening can be used. Professor Donders accepted the formula for acuteness of color-perception as $\frac{\alpha}{A}$ in which α is the visual angle at which the person examined sees the colors, and A the angle at which the examiner sees them. If the examiner can see the red and green lights through the 1 m.m. opening at a distance of five meters, and the person examined only sees them at one meter, his color perception would be one-fifth. In these cases we have to depend on the acuteness of color-sense in the eye of the examiner as the standard with which the applicant is compared, and this standard may vary considerably in different persons. Again, the distance of the candle from the colored glass is an important factor, and the red can be seen by normal eyes with the candle at a greater distance from the glass than the green. In all signal lanterns, however, the light must remain at the same distance from the lens, so in testing railway employes we may disregard this difference. Instead of taking so small an opening as 1 m.m. at 5 meters distance for the standard test for transmitted light as used in Holland, it will be found better to use a 2 m.m. hole, or about 5-64 of an inch, and to place the person to be examined at a distance of 20 feet from it. Under these conditions the opening will subtend a visual

angle of one minute at the eye, and will correspond to the width of the letters on the xx foot Snellen test card used for that distance. If we make the other openings in our diaphragm 7-64, 9-64, 3-16, 1-4, 3-8 and 3-4 of an inch in diameter respectively, we shall have a series of diameters that will nearly correspond to the width of the series of letters on Snellen's test-card, and which, at corresponding distances, will nearly subtend the uniform angle of one minute. If we consider as a sufficient standard for this test the ability to recognize red and green, either alone or combined with London smoke glass, to vary the intensity of the light, and also white light, either alone or combined with the London smoke glass, all seen under the standard angle of one minute, we can then use the other openings in this diaphragm to give a fraction which will represent the amount of color-perception as compared with this unit, just as in the case of form-vision. For instance, if the normal eye recognizes easily the colors through the 2 m.m. or 5-64 inch opening at twenty feet, and the eye examined only distinguishes them when the 9-64¹ opening is used, we call his color-perception one-half of the standard. This is not exact, and we cannot get with color-perception, by our ordinary tests, the same fine gradations of acuteness that we get with form-vision. We also find many eyes whose color-perception is more acute than this standard, just as we find eyes that can see the xx line of letters at a greater distance than twenty feet, but it furnishes us with an easy test, having direct relation to the standard of form-vision, and one which is useful in detecting defects in the central portion of

¹ The sizes of the opening in this series were chosen because twist drills of these sizes could be easily obtained, and gave holes that at the respective distances very nearly subtended the standard angle of one minute.

the retina. About five years ago I made an instrument on this principle, which has given satisfactory results, and with it the standard switch light lenses and semaphore glasses can also be used as confirmatory tests.

In a paper by Dr. Nuel of Liege, published in 1895, he states that in Belgium in the confirmatory test they consider the color-sense as sufficient if the applicant distinguishes red and green through an opening of 2 m.m. at five meters distance when lighted by an ordinary kerosene lamp. In Holland they require for color-sense in enginemen and firemen a power of distinguishing colors with both eyes open of not less than four-fifths, or in each eye separately not less than one-half, using the 1 m.m. opening as the standard, and for other specified employments a color-perception of at least three-fifths with both eyes open, or not less than one-quarter in each eye alone. For re-examination in the first class, the standard is dropped to at least three-quarters with both eyes open, or at least one-third with each separately, and in the second class, with both eyes to at least two-thirds, or, with each eye separately, to at least one-quarter, and Donder's instrument is required to be used in all these tests. I used a Donders instrument, made by Kaagenar in Utrecht, for some time, but did not find it so convenient or satisfactory as my instrument with the larger openings and greater number and variety of glasses. Even with Holmgren's worsteds it is possible to make a distinction between some of the greater variations in color-sense, for if a person is hesitating, picks up some confusion colors and compares them with the test skein, perhaps selects them and then discards them, or picks up some of the true colors, and after comparison rejects them, finally selecting none of the confusion colors, it shows that he has a feeble color-perception; if he selects with the greens some of the confusion colors, but with the

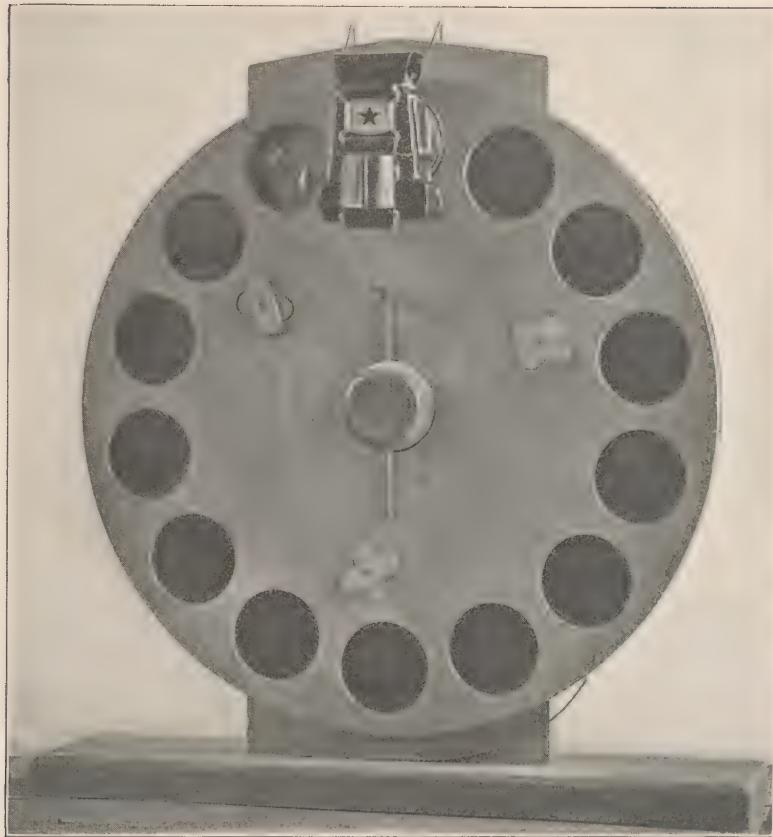


FIG. I.

Back view of Williams' apparatus for testing color-vision, showing the position of the lantern and the discs of colored glass. The colored glasses are held in place in cells made between two wooden discs, which are clamped together and can be revolved at the back of the instrument so as to bring any glass in front of the lantern, and a spring at the lower part catches lightly in grooves on the periphery of the discs, so as to centre each glass before the light. If it is desired to change the order of the glasses, or to insert new ones, the discs can be easily unclamped, and any desired change made.

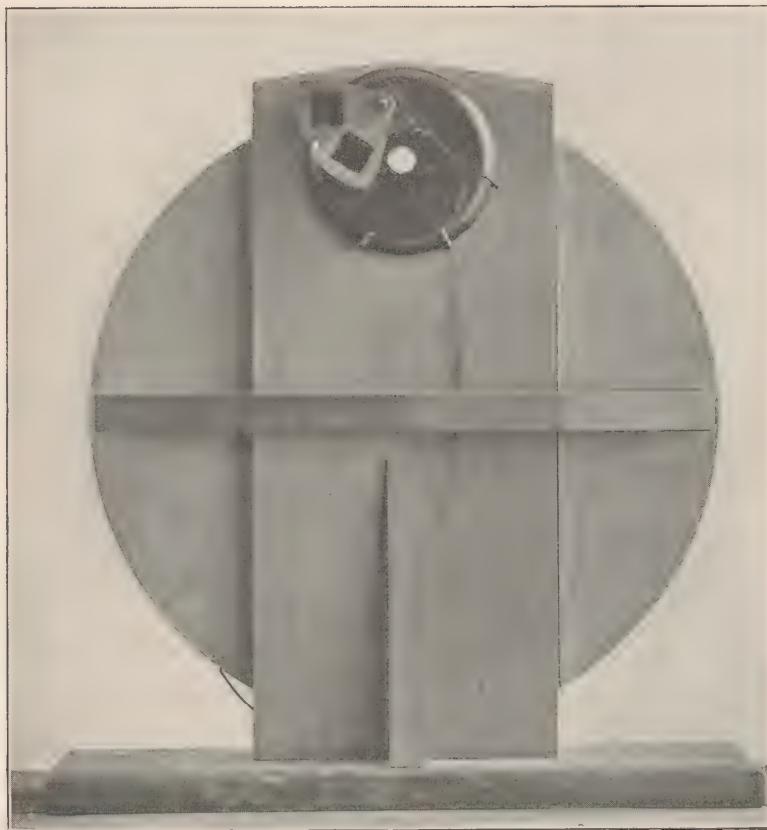


FIG. 2.

Front view, showing revolving diaphragm with graduated holes, and two London smoke glasses.

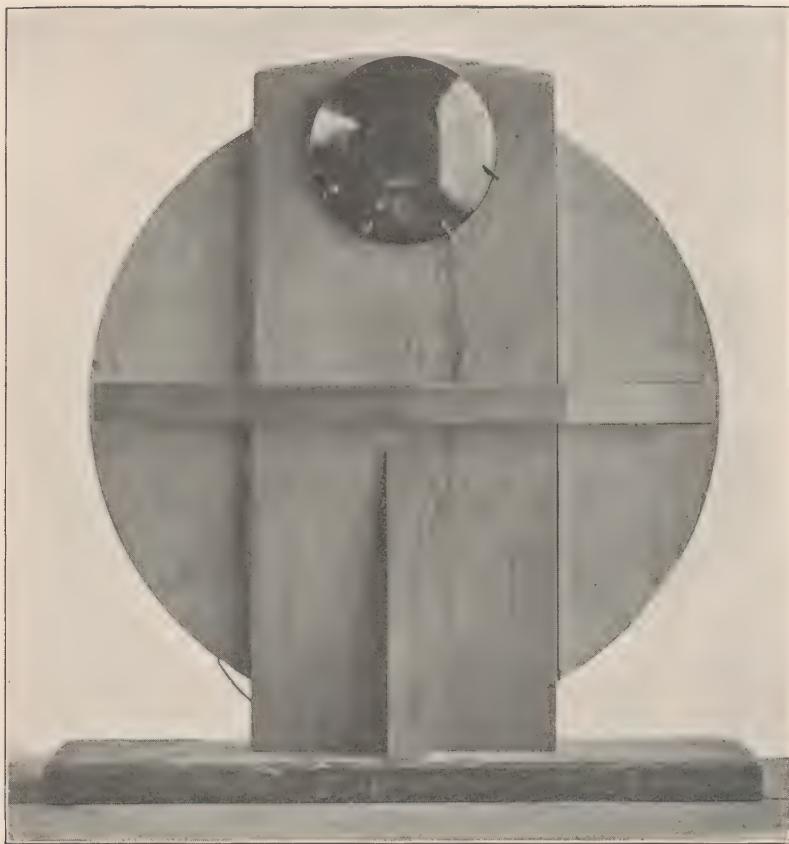


FIG. 3.

Front view, with standard switch light lens in place of the diaphragm.

pink or rose skein makes no mistake, it shows that he has an incomplete defect; but if with the green skein he selects confusion colors in addition to the greens, and with the rose skein selects with the rose colors some blues or violets, it shows he has complete defect for red, or if with the rose skein he selects in addition to rose color some greens or grays it shows he has complete defect for green. On the Burlington System I found it best to have each of the one hundred and seventeen colors of the Holmgren worsteds provided with a small brass numbered tag, which could be used to make a record of the numbers selected by the applicant, just as in the Thomson test, and each set of worsteds being carefully prepared in my office, the numbers and colors were uniform for the whole system, so that when the results of each examination were forwarded to me for approval they could be easily checked.

It is very necessary in this work to have a general supervision placed in the hands of some competent person, who can properly instruct the examiners, see that they carry out their directions and make a periodical inspection of the tests they use in order to make sure they are kept in good condition, otherwise there is danger that the examiner will become careless, or that the test cards or colors will deteriorate so that they can no longer be relied on to give proper results; the record of all examinations should also be filed in one central office.

So long as red and green signals are used for night work (and no other colors seem better adapted to this use) no applicant should be accepted for service in a position which will require him to use such signals who has incomplete or even feeble color-vision, and if the entrance examinations have been thoroughly carried out, according to Holmgren's directions, and also with transmitted lights, there will be no need of a repeti-

tion of these color tests, except as before stated where the form-vision has become impaired, or where for some special reason it seems best to repeat the examination. The tests for both form and color-vision should be made when the man is not fatigued by a long tour of duty or exposure, for it has been found that the acuteness of both form and color-perception is often diminished after two hours or more of engine work. After long runs and unusual exposure this temporary reduction in acuteness may be considerable, and it furnishes an additional argument for insisting on a high standard for such service. If one-half of normal vision were to be accepted as a minimum for each eye when the person was rested and in good health, the conditions of service might easily reduce this far below the danger point, but if a high standard is required the vision may be temporarily reduced by fatigue without becoming dangerous.

In a report on the sanitary service of the railways in Holland, presented to the International Conference in Amsterdam in 1895, it is stated: "Experience has shown that since the examination for admission has been carefully made, the re-examinations have shown scarcely any incapable men. It is also to be noted that the employes themselves in general recognize the utility and importance of these examinations." In a letter from one of the officers of the Burlington System, written to me Nov. 18th, 1896, he says that the operating officers of that system thoroughly approve of the examinations for entrance to their service, which include not only the tests for sight, color-sense and hearing, but also a general medical examination made by the medical examiners of the road, who are all well qualified physicians, and he also states that the general character and efficiency of the employes has been improved by these examinations,

which are fairly and thoroughly carried out. It seems to me that more can be accomplished in the way of improving the standards and methods used for testing sight, etc., by showing the operating officers of the railroads that it is for their own interest, and for the interest of their employes, to have such tests carefully made and to use such methods as shall be just and efficient, rather than by trying to force measures on the railroads through legislation, which is apt to be crude, and is met with opposition on the part of both the railroad companies and their employes, as being directed against their personal interests, whereas, proper methods rightly applied should meet with the approval of both officers and men.

In addition to the tests for the men, more care should be taken with the signals which the men are to use, especially in the case of colored lights. Captain Abney and others have shown the spectroscopic quality of various red and green signal lights, but it will be found in practice that a test based on the photometric quality of the lights is more important, especially in the case of persons with feeble color-sense, who depend largely on a difference of intensity to recognize the difference between the red and green lights. With reference to this point, they have kindly tested spectroscopically for me at the Mass. Institute of Technology three switch light lenses, with the following results:

No. of Lens.	Maximum wave length transmitted.	Minimum wave length transmitted.
No. 1.	7130	5820
2.	7150	5940
3.	7150	6260

All these lenses were flashed on their smooth surface with a red copper glass, and these figures show that they

all transmitted light from about the same part of the spectrum. No. 1 was so light a red that it might easily be mistaken for white when seen at a distance. No. 3 was so dark a red that it could be mistaken for green by a person defective in color sense, as has actually been done with this lens. No. 2 was a standard lens of medium intensity. Nos. 1 and 3 would have been rejected by a photometric test, such as I described at a meeting of this Society in 1895, although the spectroscope did not show much difference between them, therefore, some test based on the intensity of the transmitted light should be applied in accepting all red signal lenses.

15 Arlington St., Boston,
May, 1897.